

Reproduction and longevity of the predatory mite, *Phytoseiulus persimilis* (Acari: Phytoseiidae) and its prey, *Tetranychus urticae* (Acari: Tetranychidae) on different host plants¹

DAVID R. GILLESPIE and D.J.M. QUIRING

PACIFIC AGRICULTURE RESEARCH CENTRE, AGRICULTURE AND AGRIFOOD CANADA,
P.O. BOX 1000, AGASSIZ, B.C. V0M 1A0

ABSTRACT

The biological control of twospotted spider mites by the predator *Phytoseiulus persimilis* is usually unsuccessful on greenhouse tomato crops in British Columbia. Experiments were conducted to determine the influence of host plant on the longevity and reproduction of the predator, and on the suitability of twospotted spider mites as prey. Lifespan and reproduction of *P. persimilis* were lower on tomato leaves than on bean leaves but feeding on spider mites that had been reared on tomato or bean leaves had no effect on the reproduction or lifespan of *P. persimilis*. A strain of twospotted spider mites that came from an outbreak on a greenhouse tomato crop lived for shorter periods and laid fewer eggs when confined on tomato leaves than on bean leaves. A strain of twospotted spider mites that had been maintained on bean leaves was unable to reproduce on tomato leaves. Exudates from glandular hairs were toxic to *P. persimilis*. Glandular hairs are important in pest management on tomato crops. Their removal through breeding might make plants more susceptible to herbivores. Therefore it would be preferable to develop other methods for biological control of twospotted spider mites on tomato.

INTRODUCTION

Biological control of twospotted spider mites, *Tetranychus urticae* Koch (Acari: Tetranychidae) by *Phytoseiulus persimilis* (Dosse and Bravenboer (Acari: Phytoseiidae) is successful on wide range of greenhouse crops throughout the world (van Lenteren and Woets 1988). However, the use of this predator for biological control of *T. urticae* on greenhouse tomato crops has been unsuccessful in British Columbia, and elsewhere (Ravensburg *et al.* 1982). This has been attributed to the entrapment of *P. persimilis* on the glandular hairs on the stems and leaf petioles of tomato plants (van Haren *et al.* 1987).

It is possible that other factors associated with hairiness may also be involved in the lack of efficacy of *P. persimilis* on greenhouse tomato crops. Many mechanisms of resistance to insects and mites have been identified in tomato (Farrar and Kennedy 1991b). Several toxic and repellent chemicals, for example 2-tridecanone, are present in the glandular hairs and on the leaves of tomato plants (Farrar and Kennedy 1991b). A predator such as *P. persimilis* would be exposed to these chemicals either directly, through contact with the leaf, or indirectly, through ingestion of prey.

Many of the mechanisms of resistance in tomato are effective against *T. urticae* (Farrar and Kennedy 1991b). The degree to which the tomato plant affects reproduction and population growth in spider mite populations might aid in determining strategies for dealing with this pest.

We present here results of experiments to determine the mortality and fecundity of the predatory mite, *P. persimilis* and its prey, *T. urticae*, on tomato leaves.

MATERIALS AND METHODS

General: The spider mite strains used in this study were maintained in continuous culture on their respective host plants. The strain adapted to feeding on bean (B-strain) originated from a commercial insectary (Applied Bio-nomics Ltd., Sidney, B.C.) where it had been reared continuously on snap bean (*Phaseolus vulgaris* L.) for several years. The strain adapted to feeding on tomato (*Lycopersicon esculentum* Mill.) (T-strain) originated from an outbreak on tomato plants in a greenhouse in Surrey, B.C. in 1992.

The B-strain mites were reared on pinto beans (*P. vulgaris*) in pots on a laboratory bench. The

plants were inoculated weekly from stock materials obtained from Applied Bio-nomics Ltd. The T-strain mites were reared on excised tomato leaflets (cv Dombito, DeRuiter Seeds, Ohio) on styrofoam trays floating in water filled trays. The petioles of the leaflets were inserted through holes in the styrofoam into the water below. Fresh leaves were added to the trays as required.

The *P. persimilis* used in these experiments were also obtained from Applied Bio-nomics. Eggs of *P. persimilis* were produced for experiments by isolating 2 to 5 females on detached bean leaves on water-saturated cotton batting and providing them with abundant spider mites. The predator eggs were removed every 24 h. Females of *P. persimilis* were produced for experiments by rearing single eggs to adults on detached bean leaves with an abundant supply of spider mites (B-strain). The predators were examined daily, and the females were used in experiments within 24 h of the final molt to adult. All experiments were conducted in growth chambers at 26°C under 16 h of light from cool white fluorescent tubes.

Twospotted spider mites: The effects of host plant species and spider mite strain on egg hatch, development, and survival to adult of *T. urticae* were determined on leaf discs on water-saturated cotton in petri dishes. Eight discs, 1 cm in diam., of each plant species were placed in rows of four on water-saturated cotton batting in each of ten, 9.2 cm square, plastic Petri plates.

A single spider mite egg (< 24 h old) was placed on each leaf disc. Four bean leaf discs in each plate received B-strain mite eggs, and four received T-strain mite eggs. Four tomato leaf discs received T-strain mite eggs and four received B-strain eggs. The spider mites were observed daily through their development. Molts were determined by the presence of cast skins. Spider mites were moved to fresh leaf discs as required.

The effects of the plant host on reproduction in the two strains of spider mite were determined in an identical experimental design to that above, except that adult females (<24 h old) were placed on leaf discs. These females were obtained by rearing spider mites individually on their respective host plants from the protonymph stage. Females at the quiescent deutonymph stage were confined with males. On molting to adult, both the female and the male were transferred to either bean or tomato leaf discs in the experiment. Eggs were counted and removed daily. The mites were transferred to fresh leaf discs as required. Results were analyzed as a factorial design by analysis of variance (Proc GLM, SAS Institute 1992).

Predator mites: To determine if plant species affected reproduction of *P. persimilis*, a single female (<24 h old) was placed with a male on either a bean leaf disc infested with B-strain spider mites or on a tomato leaf disc infested with T-strain spider mites. Predator eggs were counted daily. Predators were transferred to fresh leaf discs as required. The results were analyzed by T-test.

Development time of *P. persimilis* fed on the two different strains was determined on 2 cm diam. plastic discs floating on water-saturated cotton batting in a Petri dish. Four discs were placed in each Petri dish and a single egg of *P. persimilis* was placed on each disc. After the eggs hatched, two of the predators were fed eggs of spider mites reared on bean plants, and two were fed eggs of spider mites reared on tomato plants. Eggs were collected with a camel-hair brush from active spider mite colonies. An excess supply of eggs was placed on each disc. Molts were determined by the presence of cast skin. The results were analyzed by T-test.

To determine if the effects seen in the previous experiment were due to plant species or spider mite strain, adult female *P. persimilis* (<24 h old) were placed on styrofoam discs 2.5 cm in diam. Mixed age populations of spider mites were provided daily on fresh pieces of leaf. The prey were either B-strain spider mites on a bean leaf, B-strain mites on a tomato leaf, T-strain mites on a tomato leaf, or T-strain mites on a bean leaf. Predator eggs were counted and removed daily. Only records for those females that died of natural causes on the disc surface were used for analysis. Mites that abandoned the discs and drowned were not included in the analysis. Results were analyzed by a factorial design analysis of variance (Proc GLM, SAS Institute, 1992).

The toxicity of exudates from glandular hairs of tomato to *P. persimilis* females was determined by exposing them directly to glandular hairs, or to an aqueous solution of exudates, or to water. Twenty mites were exposed directly to glandular hairs. These were held on the tip of a moist camel-hair brush and lightly touched to 30 to 40 glandular hairs on a piece of tomato stem. They were then placed on a sheet of filter paper to recover, then held for examination. Twenty

mites, selected at random, were exposed to exudate solution. These were dipped for 4 sec in the solution, placed on filter paper to dry, and then held for examination. The solution was prepared by collecting exudate from the tips of glandular hairs, allowing this to dry overnight, then dissolving 0.28g of the dried exudate in 2 ml of distilled, de-ionized water. Twenty mites were similarly dipped in distilled, de-ionized water. After 24 h, the dead mites were counted. Results were analyzed by a χ^2 test for goodness of fit.

RESULTS

Twospotted spider mites: Neither host plant nor mite strain had a significant effect ($p>0.05$) on the proportion of eggs hatching (Table 1). There was a significant interaction ($F=18.11$, $p>0.001$) between host plant and mite strain with respect to survival of mites from hatch to adult. There was high mortality of B-strain spider mites on tomato leaf discs, but not on bean leaf discs, and low mortality of tomato strain spider mites on both tomato and bean. Due to high mortality of B-strain mites on tomato leaf discs data on development of this strain were not included in the analysis. Instead, host plant/mite-strain combinations were used as three treatments in a two-way analysis of variance with sex of the mite as the other main effect. There was no interaction between sex of mite and treatment ($p>0.05$). Neither sex of the egg nor host-plant/mite-strain combination had an effect on the time to egg hatch ($p>0.05$; Table 2). Female mites took longer to develop from larvae to adults than males ($F=4.71$, $p=0.0331$). Treatment

Table 1

Mean number of eggs hatched, and survival to adult in 10 cohorts of 4 mites of each strain on bean and tomato leaf discs.

Host plant	Mite strain	Number hatched of four (N=10)	Proportion surviving of four (N=10)
Bean	Bean	3.6	0.90
	Tomato	3.7	0.85
Tomato	Bean	3.4	0.03
	Tomato	3.5	0.88
Mean Square Error		0.3167	0.1721

Anova Results

Host plant	<i>F</i> (<i>p</i>)	1.26 (0.2685)	15.42 (0.0004)
Mite strain	<i>F</i> (<i>p</i>)	0.32 (0.5776)	13.37 (0.0008)
Host x Strain	<i>F</i> (<i>p</i>)	0.00 (1.000)	18.11 (0.0001)

Table 2

Mean (N, Standard Error) number of days for tomato and bean strain spider mites to complete development on tomato and bean leaf discs.

Host plant	Mite strain	Male		Female	
		Egg	Total*	Egg	Total*
Tomato	Tomato	5.3a	10.0a	5.0a	11.2a
		(7, 0.18)	(7, 0.90)	(19, 0)	(19, 0.46)
Bean	Tomato	5.2a	5.2b	5.3a	5.7b
		(9, 0.15)	(9, 0.36)	(18, 0.11)	(18, 0.27)
Bean	Bean	5.1a	5.1b	5.2a	5.6b
		(19, 0.11)	(19, 0.19)	(10, 0.20)	(10, 0.16)

* Time from egg hatch to molt to adult

Means in a column followed by the same letter are not significantly different.

Table 3

Egg production and survival of bean strain and tomato strain adult female twospotted spider mites on bean and tomato leaf discs.

Host plant	Mite strain	N	Number of Eggs	Days Alive
Bean	Bean	9	49.7	13.2
	Tomato	15	38.7	16.6
Tomato	Bean	10	0.6	6.0
	Tomato	8	2.6	10.0
Mean Square Error			27.8203	7.4501
<i>Anova Results</i>				
Host plant	<i>F</i> (<i>p</i>)		22.75 (0.0001)	8.55 (0.0058)
Mite strain	<i>F</i> (<i>p</i>)		0.26 (0.6124)	2.43 (0.1270)
Host x strain	<i>F</i> (<i>p</i>)		0.55 (0.4637)	0.02 (0.8960)

Table 4

Mean development and reproduction parameters (\pm standard error) for *Phytoseiulus persimilis* feeding on spider mites on bean or tomato leaves (N = 10).

	Host plant:	Bean	Tomato
Development Time		2.6 \pm 0.18	2.8 \pm 0.17
Total Eggs Laid		56.0 \pm 5.67	38.1 \pm 3.34*
Days of Oviposition		13.9 \pm 1.50	9.6 \pm 0.87*
Lifespan		20.7 \pm 2.71	11.3 \pm 0.60*
Eggs laid per day		3.0 \pm 0.46	3.4 \pm 0.28

*Significant effect of host plant (T-test, $p < 0.05$)

(host-plant/mite-strain combination) had a significant effect on the time for development from egg to adult ($F=134.96$; $p < 0.0001$). Both male and female T-strain mites required significantly longer to develop on tomato than either T-strain mites on bean or B-strain mites on bean.

Spider mites produced significantly fewer eggs on leaf discs of tomato than they did on leaf discs of bean (Table 3). Spider mite lifespan was also shorter on leaf discs of tomato than on leaf discs of bean. Strain had no effect on either egg production or longevity of spider mites.

Predator mites: There was no effect of spider mite (prey) strain on development time of *P. persimilis* on leaf discs (Table 4). Females on discs of tomato leaf laid fewer eggs over a shorter period and had shorter lives than females on discs of bean leaf (Table 4). There was no effect of host plant species on the rate of oviposition.

When *P. persimilis* were confined on styrofoam discs and supplied with prey on leaf pieces, there was no effect of host plant leaf pieces on the life span or fecundity of female *P. persimilis* (Table 5). Females that were fed B-strain mites lived for a significantly shorter time than females that were fed T-strain mites irrespective of the plant species on which the spider mites were presented.

Ten percent of females of *P. persimilis* died after exposure to water, 50% died after exposure to a solution a glandular hair exudates, and 85% died after direct contact with glandular hairs. These were significant differences ($\chi^2=22.6$, $p < 0.05$).

DISCUSSION

The twospotted spider mite, *T. urticae*, is broadly polyphagous. However, some spider mite populations are selectively adapted to only some of the plants that are part of their host range (Fry 1989). It is probable that no spider mite population is able to feed and reproduce on all of

the known hosts. The T-strain of spider mites used in this study originated from an outbreak on a tomato crop in a commercial greenhouse. However, it was able to use bean, *P. vulgaris*, as a host, and survived and reproduced better on bean than on tomato (Table 3). There were no differences in reproduction or survival between the B- strain and the T-strain on bean. On tomato, the B-strain of *T. urticae* was virtually unable to reproduce. Very few immatures survived to reproduce, and females placed on tomato laid few eggs.

The reproductive abilities of the T-strain of *T. urticae* are so reduced on tomato that it appeared surprising that this strain was able to survive on tomato, let alone generate an outbreak. However, in laboratory culture this strain reproduced rapidly on excised leaves of tomato. The major difference between the laboratory culture and the experiments described here was that many spider mites were used to start a culture, whereas a single mite was used in experiments. The large number of mites used to inoculate the laboratory colony produced copious silk. Mites tend to walk on the silk and would therefore have been isolated from the leaf surface. Tomato plant glandular hairs contain many substances that are toxic to twospotted spider mites (Farrar and Kennedy 1991b). The silk would tend to protect the mites from the effects of the hairs and the larger number of mites on the leaf would tend to dilute exposure to glandular hair substances.

The strain of spider mite had no effect on the fecundity of the predator, *P. persimilis*. In an initial experiment (Table 4) fecundity was lower for females feeding on T-strain spider mites on tomato leaves than for those feeding on B-strain spider mites on bean leaves. On styrofoam discs, neither the strain of spider mites nor the plant species on which they were provided had any significant effect on reproduction in the predator. This is probably because the predators did not have to spend all of their time on the plant section provided, but could move about on the styrofoam disc, thus avoiding contact with the glandular hairs.

Predators that were fed on B-strain spider mites had shorter lives than predators fed on the T-strain mites (Table 5). In these results the interaction between host plant and spider mite strain was not significant. However, it is large enough to indicate that the significant effect of spider mite strain on lifespan could have resulted from the short lifespan (15.3 days) of *P. persimilis* that were fed B-strain spider mites on tomato leaf pieces. Lifespan of *P. persimilis* in all other treatments was greater than 18 days. Mortality among B-strain mites on tomato leaves could have reduced the number of prey available to *P. persimilis*. Plant resistance characters are known to affect the biology of natural enemies, even though Wheatley and Boethel (1992) showed that resistance to spider mites in soybeans (*Glycine max*) had no effect on *P. persimilis*. However, other natural enemy associations are affected by resistance characteristics in soybeans (Orr and Boethel 1986, Rogers and Sullivan 1986, Yanes and Boethel 1983). Resistance to *Manduca* spp. (Lepidoptera: Sphingidae) in tomato has toxic effects on the parasitoid *Telenomus sphingis* (Hymenoptera: Scelionidae) (Farrar and Kennedy 1991a).

Table 5

Numbers of eggs laid and lifespan for *Phytoseiulus persimilis* females held on styrofoam floating discs and fed spider mites reared on either bean or tomato leaves (N = 10).

Host plant	Mite strain	Total Eggs	Lifespan (days)	Eggs per day
Bean	Bean	53.1	18.1	3.2
	Tomato	54.9	18.9	3.1
Tomato	Bean	44.2	15.3	3.0
	Tomato	42.6	19.9	2.4
Mean Square Error		23.95	3.9	1.53

Anova Results

Host Plant	<i>F</i> (<i>p</i>)	1.96 (0.1701)	0.51 (0.4801)	0.98 (0.3283)
Mite Strain	<i>F</i> (<i>p</i>)	0.00 (.9895)	4.58 (0.0392)	0.53 (0.4714)
Host x Strain	<i>F</i> (<i>p</i>)	0.05 (0.8236)	2.27 (0.1407)	0.37 (0.5475)

The host plant of the spider mite upon which *P. persimilis* fed did not greatly affect the biology of the predator. Females of *P. persimilis* confined on tomato leaflets have a shorter lifespan than females confined on bean leaves. As a consequence, the number of eggs laid is reduced, and population growth and predation would be reduced. This effect is due to contact with leaf, not the consumption of prey. Eating B-strain mites fed on tomato reduced the lifespan of *P. persimilis*. The cause of this was not clear.

Up to 75% of *P. persimilis* die moving from leaf to leaf on tomato plants (van Haren *et al.* 1987). If the reproduction of the remainder is reduced by up to 40% as a result of reduced lifespan on leaf blades, then it would appear that enormous numbers of predators would have to be introduced into tomato crops to offset these effects

Resistance in tomato plants to spider mites can be affected to some degree by environmental factors. Increased fertilization reduces resistance through lowering both glandular hair densities and 2-tridecanone levels (Barbour *et al.* 1991). Glandular hair density is conversely increased in long-day, high light level conditions (Kennedy *et al.* 1981). Glandular hair density and other resistance factors might be reduced through breeding. However, resistance to pests based on glandular hairs is important for preventing feeding by many species of herbivores (Farrar and Kennedy 1991b), and should not be discarded for the sake of single predator/prey association. It would be preferable to develop alternative strategies for releasing and managing *P. persimilis* in tomato crops, or to seek other predator species that are not affected by the resistance mechanisms of tomato.

ACKNOWLEDGEMENTS

We thank J. Treurneit for technical assistance on parts of the project, and Applied Bio-nomics Ltd., Sidney, B.C., Canada for the supply of spider mites and predators.

NOTE

1. Contribution number 516 from the Pacific Agriculture Research Centre, Agassiz, B.C.

REFERENCES

- Barbour, J.D., R.R. Farrar Jr. and G.G. Kennedy. 1991. Interaction of fertilizer regime with host-plant resistance in tomato. *Entomol. exp. appl.* 60: 289-300.
- Farrar, R.R. Jr. and G. Kennedy. 1991a. Inhibition of *Telenomus sphingis* an egg parasitoid of *Manduca* spp. by trichome/2-tridecanone-based host plant resistance in tomato. *Entomol. exp. appl.* 60: 157-166.
- Farrar, R.R. Jr. and G. Kennedy. 1991b. Insect and mite resistance in tomato pp.121-142 *In* Kaloo, G. (ed.) Genetic improvement in tomato. Springer-Verlag. Berlin, West Germany. Monographs on Theoretical and Applied Genetics.
- Fry, J.D. 1989. Variation among populations of the twospotted spider mite, *Tetranychus urticae* Koch (Acari: Tetranychidae), in measures of fitness and host-acceptance behavior on tomato. *Environ. Entomol.* 17: 287-292.
- Haren, R.J.F. van, M.M. Steenuis, M.W. Sabelis, and O.M.B. De Ponti. 1987. Tomato stem trichomes and dispersal success of *Phytoseiulus persimilis* relative to its prey, *Tetranychus urticae*. *Exp. Appl. Acarol.* 3: 115-121.
- Kennedy, G.G., R.T. Yamamoto, M.B. Dimock, W.G. Williams and J. Bordner. 1981. Effect of daylength and light intensity on 2-tridecanone levels and resistance in *Lycopersicon hirsutum* f. *glabratum* to *Manduca sexta*. *J. Chem. Ecol.* 7: 707-716.
- Lenteren, J.C. van, and J. Woets. 1988. Biological and integrated pest control in greenhouses. *Annu. Rev. Entomol.* 33: 239-269.
- Orr, D.B. and D.J. Boethel. 1986. Influence of plant antibiosis through four trophic levels. *Oecologia* 70: 242-249.
- Ravensburg, W.J., J.C. van Lenteren and J. Woets. 1982. Developments in application of biological control in greenhouse vegetables in the Netherlands since 1970. *International Organization for Biological Control, West Palearctic Regional Section Bulletin VI/3*: 36-48.
- Rogers, D.J. and M.J. Sullivan. 1986. Nymphal performance of *Geocoris punctipes* (Hemiptera: Lygaeidae) on pest-resistant soybeans. *Environ. Entomol.* 15: 1032-1036.
- SAS Institute Inc. 1992. SAS/STAT users guide. Version 6, Fourth Edition, Volume 1, Cary, NC: SAS Institute Inc. 1992. 943 pp.
- Wheatley, J.C. and D.J. Boethel. 1992. Populations of *Phytoseiulus persimilis* (Acari: Phytoseiidae) and its host, *Tetranychus urticae* (Acari: Tetranychidae), on resistant and susceptible soybean cultivars. *J. Econ. Entomol.* 85: 731-738.
- Yanes, J. Jr. and D.J. Boethel 1983. Effect of a resistant soybean genotype on the development of the soybean looper (Lepidoptera: Noctuidae) and an introduced parasitoid, *Microplitis demolitor* Wilkinson (Hymenoptera: Braconidae). *Environ. Entomol.* 12: 1270-1274.